CONCERNING THE STRUCTURE OF AGELACRINITES AND STREPTASTER, EDRIOASTEROIDEA OF THE RICHMOND AND MAYSVILLE DIVISIONS OF THE ORDOVICIAN.

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CONTENTS.

Introduction and Sources of Material.

The study of living animals gives many clues to the life history of closely related forms found fossil. There are, however, groups of fossil animals which have no present-day representatives and these groups are far less easy to understand.

The Cystids are a division of the Echinoderms which disappeared completely with the end of the Palaeozoic. The study of any cystid can, therefore, be aided only by distant analogies from the groups most closely related which are still in existence. Of the four divisions of the Echinoderms now extant the Crinoids are the most primitive and therefore should give most light on extinct forms.

I wish to attempt a study of one of the longest lived of the Cystids, Agelacrinites, Vanuxem. This genus is found from the Ordovician to the Carboniferous inclusive, according to Zittel, and the time of its greatest abundance is the Ordovician. The forms found in the Richmond and Maysville divisions of the Ordovician will be the only ones considered in this study.

The material worked on comes from several definite horizons. These are:

1. Several localities in the Corryville.
2. At the base and near the top of the Saluda in Franklin and Ripley Counties, Indiana.
3. In the Oakland (Elkhorn) division on Dutch and Cowan's creeks, Clinton County, Ohio.
4. At the top of the Richmond near Lawshe, Adams County, Ohio.
5. Near the top of the Richmond (Elkhorn) near Eaton, Ohio, and on Elkhorn creek, Indiana.

Additional material has been secured from collections by C. B. Dyer, of Cincinnati, and D. T. D. Dyche, of Lebanon, Ohio. These specimens are probably from the Corryville levels or below them (No. 1).

When conditions of water, its clearness and depth were satisfactory these little echinoderms were quite abundant. They lived attached to the larger shells at the bottom, clam valves being most common locations in the Richmond and the large brachiopod, Rafinesquina alternata, carrying most of the Maysville specimens. They have been found on the outer surface of a sponge, *Dystactospongia madisonensis* Foerste, on corals, *Tetradium*, on several different clams, *Ischyrodonta*, *Byssonychia*, etc., on *Hebertella*, *Platystrophia* and other large brachiopods and, notably on Cowan's Creek, in Clinton County, loose and inverted.

In this case it would seem possible (1) that the shell on which the Agelacrinites was attached was turned over by wave action and that in death the animal separated from its point of attachment and so was found lying aboral side uppermost or else (2) that the animal was not permanently attached, but could free itself and reattach.

Zittel's description of the family of the Agelacrinidæ Hall is as follows, (Vol. I, Part I, p. 187): "The calyx composed of a large number of small, irregularly arranged plates and either furnished with a short stem or fixed by a broad base. Plates pierced by pores usually united in pairs. Mouth central, anus excentric, provided with a valvate pyramid (of plates). Arms placed in radial grooves on the exterior of the calyx and protected by covering plates."

Agelacrinus: "Calyx in the form of a depressed or convex disk, stemless and attached by the entire under surface. Composed of numerous small polygonal, usually imbricating plates which are perforated by fine pores, mouth surrounded by four oral plates; radiating from this are five small, more or less curved arms which are embedded in grooves on the outer surface and are protected by a double row of covering plates."

Following Bather the recent classification puts *Agelacrinites* into the family *Edrioasteroidea*, Billings. All evidence at hand indicates that *Agelacrinites* differs from *Edrioaster* and *Lepidodiscus* in that the aboral wall contains no plates of the type which Bather calls the concentric frame plates and which may have been attached to the substratum.

The Richmond *Agelacrinitidæ* have the rays arranged in one of several ways. They are either all straight as in *A. rectiradiatus*, all turned in a counter-clockwise or contra-solar direction or else four of them are so oriented and the fifth is reversed at its outer end so as to produce one inter-radial area much larger than the others.

In this larger space, which may be called the posterior inter-radial space, are to be found the anal pyramid and an opening which is probably the opening for the water-vascular system, the hydropore.

If the specimen be so placed that the inter-radius containing the anal pyramid is toward the observer, the ray at the left is known as No. 1 and the one at the right No. 5. Food-grooves 1 and 2 are closely related to each other and food-grooves 4 and 5 are also closely related to each other. Food-groove 3, the anterior ray, pointing directly away from the anal inter-radius is separated from the right and left pairs of rays by some distance as measured on the food groove. Near the base of this ray are often found three especially large plates, the peristomial or mouth plates.

The genus *Streptaster* Hall differs from *Agelacrinites* in that it has proportionately larger and longer plates covering the food-grooves and proportionately smaller inter-radial plates. In most cases as one looks down on a specimen of this genus the ends of the palisade-like covering plates are all that is visible and no trace of the inter-ambulacral covering is evident.

Historical Review.

(Arranged in the order of description).

Agelacrinites cincinnatiensis Roemer. Described in 1851 in the Verh. Naturh. Ver. fur Rheinl, und Westphal. Vol. VIII, p. 372, Figs 3a, b.

I quote Hall's description of the fossil, 1866–72. "It has been a moderately convex disc usually with a diameter of ½ to ¾ of an inch, though it sometimes reaches a diameter of nearly one inch which is about the size of the one figured by Dr. Roemer. The disc is composed of numerous imbricating scale-like plates; the rays all curving, four sinistral and one dextral the intermediate areas composed of large plates. The mouth, anal or ovarian aperture situated subcentrally in the largest area and surrounded by a pyramid of small triangular plates.

Agelacrinus Dicksoni Billings 1858, described in the Canadian Organic Remains, Decade 3, p. 84, pl. 8. All the arms of this species are counter clockwise, the anal pyramid is described as an orifice surrounded by small plates. The type came from the Trenton limestone, Chaudiere Falls, Ottawa, Canada. Bather makes this the type of a new genus, *Lebetodiscus*. Geol. Mag. V, vol. 5, pp. 543-550, pl. 25.

Agelacrinus Billingsi Chapman 1860: No description of this fossil is attainable other than that derived from Clarke, New *Agelacrinites*, in which *A. Billingsi* from the Trenton is said to be straight armed.

Agelacrinus pileus Hall, 1866–72: "Body subglobose or globular bellshaped, attached by the smaller extremity which is composed of small squamiform plates. Rays from the top of the dome and curving gently down the sides; four sinistral and one dextral; the dextral and one sinistral surround the posterior inter-radial space. The rays are formed by two ranges of lanceolate plates, their ends pointed and interlocking over the arm grooves, their bases originating in a transverse pyramid formed by the union of two bifurcating or V-shaped plates, one on each side of the base of the anterior ray, and a single shield-shaped plate which is situated at the upper extremity of the posterior inter-radial area. The extremities of the rays appear to have been subsessile. The lateral arms are in pairs, the anterior arm being separated from them by the V-shaped plates. Inter-radial areas distinct, the posterior one quite large and composed of numerous very small plates. Ovarian (anal) aperture situated subcentrally in the largest. inter-radial area."

Streptaster vorticellatus Hall, 1866–72: "All arms sinistral. Marginal portion of disc several ranges of minute squamiform plates. Inner portion of disc occupied by five elevated sinistrally curved and closely coiled rays or arm grooves, the curvature of each ray making about ¼ a volution. Rays composed of a double ray of lanceolate spatulate plates which interlock at their upper ends to cover the arm grooves. The plates forming the outer curvature of the rays are the longest and inclined at a lower angle than those of the inner side. The inner ends of the rays terminate in a solid pyramid formed by the union of the two bifurcating or V-shaped plates and one shield-shaped plate. Inter-radial areas very small, hardly perceptible. Ovarian (anal) aperture minute, situated near the bases of the postero-lateral rays."

Streptaster septembrachiatus Miller and Dyer, 1878: This seems merely an example of duplication of parts, a seven rayed specimen of the preceding species. I have a medusa which has five radial canals instead of the usual four, but it could hardly be called a new species.

Agelacrinus warrenensis James, 1883, The Palaeontologist, No. 7, p. 58, Plate II, Figs, 3, 3a. "Body circular, varying in diameter from ¼ to ½ inches or more. Attached to the convex valves of *Strophomena* (*Rafinesquina*) and probably other foreign substances. The under side concave or otherwise conforming to the surface grown upon. Disc composed of squamiform plates overlapping inward from the periphery. The plates of the outer margin very small and arranged in a narrow rim all around the narrow plates taking their place abruptly. About one line a little more inward the surface becomes suddenly depressed, causing quite a sharp outward ridge, in most cases all around, by the projecting edges of the plates and then rises, gently at first, but abruptly nearer and to the center forming a somewhat prominent dome. The rays or arms nearly hidden by the imbricating plates in all the specimens examined, but occasionally the arms are partly but indistinctly shown as is the case in the figured specimen, etc."

Dr. Foerste doubts the validity of this species and considers it merely a young *A. cincinnatiensis*. Fig. 27, Plate V, is the photograph of the type specimen of Dr. Dyche, never before published.

Agelacrinus holbrooki James: Described in the Palaeontologist in 1878 and redescribed and figured in 1887 in the Jour. Cin. Soc. Nat. Hist.

Body circular, subglobose. Disc composed of many thin plates, those in the inter-radial areas pentagonal or hexagonal, outside squamiform, imbricating; margin of disc composed of numerous small cuneiform and variously other shaped plates. Arms or rays not raised above the surface of the disc, four sinistral and one dextral ray, each composed of two rows of interlocking pieces. Ends of rays curving quite sharply upward and inward, making nearly a semicircle to near the center of the inter-radial areas and terminating in a blunt, club-shaped form.

Ovarian (anal) aperture situated subcentrally in the area between the dextral and one of the sinistral rays, depressed and composed of ten cuneiform pieces and an outer row of small thin plates placed apparently on their edges. The end of the dextral ray passes into or against the plates of the ovarian aperture."

Agelacrinus faberi Miller, 1894: One specimen only. The distinguishing character, "surface of all the plates is densely and beautifully tuberculated." The specimen according to Foerste is merely an *A. pileus* covered by an over-growth of some *Dermatostroma*.

Agelacrinus austini Foerste, 1914: "Characterized chiefly by its small size. Very moderate convexity, exposed part of the lateral covering plates ovate triangular in form, spaces between adjacent plates occupied in each case by one of the central or median series of covering plates of which a relatively greater length frequently is exposed than is the case of any other known species. Squamose inter-ambulacrals rather few. Anal pyramid, outer circle 6 ovate triangular plates, probably an inner circle of about the same. Inner band of peripheral ring one circle of large plates. Above this one circle graduating into the inter-ambulacral series, below this a third series graduating into the successively smaller plates forming the outer or marginal series of the peripheral ring. Peristomial plates believed to include corresponding to L, R and P."

Streptaster reversata Foerste, 1914: Eden shales. Characters of preceding Streptasters except that the direction of the tip of ray 5 is reversed as in *Agelacrinites*. Foerste maintains that this species is most closely related to *A. pileus* among the *Agelacrinites*.

Agelacrinites rectiradiatus Shideler. (Published with this article; see description). Figure 30, plate 5, and other figures.

Discussion of the Skeleton.

THE PERIPHERAL RING.

The rim of the disc of *Agelacrinites* is a very noticeable feature. Bounding the central radial and inter-radial spaces are a number of plates of the largest size which stand approximated in a vertical position or nearly so. Outside of these rows of large plates the plates decrease rapidly in size to the edge of the animal where they are very small.

Of what use were these two divisions in the peripheral ring? Foerste 1914, (p. 407) maintains and with reason that the outer portion was mobile and was the superficial protection of the fleshy margin, which, closely applied to the substratum, held the organism in place. He suggests that the finding specimens loose indicates that they were able to free themselves and reattach. This is paralleled among the *Holothuria* by the recent *Psolus fabricii*. "In life they attach themselves with the tightness of a chiton to the surf-beaten rocks where they live."—(From letter, H. L. Clark). A specimen collected by C. B. Dyer gives definite evidence that the outer margin was, if not actively mobile, at least adaptable under pressure. A large *A. cincinnatiensis* is attached close to a *Lichenocrinus*, the base of some small crinoid. Although *Lichenocrinus* is often found mis-shapen where conditions did not permit it to develop its circular form, this *Lichenocrinus* is essentially symmetrical and the margin of the *Agelacrinus* is deformed by it. The pressure acted on the margin of the *Agelacrinite* for some little distance beyond the *Agelacrinite* each way, indicating that the marginal skeleton was somewhat stiff rather than easily pressed inwards.

According to Foerste the inner larger plates of the peripheral ring make a rigid band. In my opinion while this band may have been rather firmly locked horizontally because the circular shape is preserved in most of the fossils, it must have been capable of some, if not great, vertical extension. The overlapping of so many rows of heavy plates (in *A. cincinnatiensis* and *Streptaster* at least) for their full vertical dimension would give a lateral support to the disc out of all proportion to the rest of the skeleton. May it not be possible that in the living cystid these plates did not overlap vertically to so great an extent as in the fossil so that the individual could be extended upward for a greater distance from the point of support. This would give more visceral space.

In a fragment of *A. cincinnatiensis* Plate II, Fig. 2, there are eleven plates side by side in this inner portion of the peripheral ring. Seven of these show at the surface and the other four are covered. The height of these plates measuring up from the substratum and beginning on the side toward the disc is as follows: 1, 1.5, 2, 1, 1.5, 1.5, 1.25, 1, .75, 1, 1, in mm. Then follow three rows of plates, the marginal zone, decreasing to about .5 mm. in height. Adding the measurements of the lower plates there is a total height of 12.5 mm. If these plates were in a membrane the contraction of circular muscles might have projected the animal out to the height of 12.5 mm. (disregarding the over-lap). This section is shown drawn with camera lucida on Plate VII, Fig. 46.

The presence of a heavy muscular wall would explain the perfect condition of the peripheral ring as well as if it (the peripheral ring) were assumed to be rigid, for the plates, if imbedded in a muscular wall, would be held in a definite position with reference to each other for some time after the death of the animal. Often the positions of the plates in the ring indicates that they have been permitted to drop gradually downward. The bottoms of the plates are found wedged together, while the tops flare outward and inward. This wedging of the plates of the inner part of the peripheral ring shows even better in specimens of the genus *Streptaster*, and *Streptaster* may have been more extensible than *Agelacrinites*.

Most of these rim plates had processes on their aboral surfaces, the larger plates as many as three processes and the smaller marginal plates one. These processes are shown in photographs 21, 22, 23 of *A. austini* var lawshe. Not all the plates are sufficiently well preserved to show such processes, but whenever conditions are favorable the processes are found.

These may be the specific points of attachment of the muscles of the muscular wall in which or on which the plates were imbedded.

COVER PLATES.

There are five "arms" on these animals, either flush with the general surface or elevated above it, depending on the species and also on the conditions of fossilization. These arms or rays are the external evidences of the food grooves, the device for obtaining more food than a simple mouth opening would be able to furnish the animal.

These food grooves are primarily trimeric in their arrangement, one extending to the left of the anal pyramid, one to the right of this pyramid and one directly away from it or in the anterior direction. All *Edrioasteroidea*, as far as I can learn, have these right and left extensions modified by dichotomous branching so that there are five rays and parts of the food groove instead of three.

Beginning with the left ray by the anal pyramid as 1, these rays are numbered clock-wise around the disc to 5 which is the reversed ray on the right of the anal pyramid except in some *Streptasters*. Number 3 is therefore the anterior ray.

In *A. cincinnatiensis*, *A. holbrooki* and *A. austini* the cover plates are arranged on each ray in two double rows while in *A. pileus*, *A. rectiradiatus* and others the cover plates seem to arch over the food groove as single pairs of plates. One can select a series of stages in the crowding of the cover plates.

Taking *A. rectiradiatus* as the simplest form, since in this species there is no complication with curving rays, we find cover plates whose free ends interlock or alternate along the mid-line of the groove. Diagrams of this arrangement are shown on Plate IX, Figures 54 and 56. There is usually a projection on the side of the plate nearest the mouth and the plate as seen from the side is heavy. Fig. 49, Plate VIII.

A. pileus as described by Hall and by Foerste and as far as my specimens give evidence, has but the two covering plates, one row on each side arching over the food groove.

A. austini, according to the description of the species as given by Foerste, shows besides the lateral covering plates the central or median series of covering plates, of which "a greater length frequently is exposed than in the case of any other known species." See Plate III, Figure 14, Plate VIII, Figure 50A.

In *A. cincinnatiensis* is found perhaps the greatest differences between the lateral and median rows of covering plates. Plate II, Figure 8, and Plate VIII, Figure 51A and 51B. The outer covering plates are grooved on their sides and the cylindrical median plate fills the space left by the grooving of two adjacent lateral plates. Its free end only is visible, alternating with the opposite median plate and both entirely covered from the sides by the two rows of lateral covering plates.

A weathered part of the tip end of an arm of *A. cincinnatiensis*, Plate II, Figure 11, gives the clue to these different types of arrangements of the cover plates. Only one half of the ray is left. At the distal end of the ray the plates are side by side in one series as in *A. pileus*.

As one looks proximally he finds every other plate dropping downward and toward the food groove. This is approximately the present condition in *A. austini*. Still nearer the mouth the alternate arrangement, a large lateral row of cover plates and a small median row is the normal condition that characterizes *A. cincinnatiensis*.

A young specimen of *A. cincinnatiensis*, 6 mm. in diameter, from the Corryville at Mason, Ohio, shows the primitive condition of cover plates. (Figure 29A, Plate V). The food grooves are but slightly bent. In one ray there are six plates on each side of the groove and as they have, as yet, not been crowded in the course of their development the plates are even and side by side as in *A. rectiradiatus* and *A. pileus*. It is possible that the next to the first plate at the base of the ray No. 1 is dropping inward and will take position as one of the median cover plates, producing the double row on each side, which characterizes *A. cincinnatiensis*. If so, the growing point of the food grooves is at the proximal end of the ray by intercalation of plates rather than at the distal end by addition of plates.

This crowding together of the cover plates is correlated with an increase in length of the food grooves. Again *A. rectiradiatus* furnishes the primitive straight stages. *A. austini*, Plate III, Figure 13 and 14, *A. pileus*, Plate I, Figure 3 and 4, *A. cincinnatiensis*, Plate I, Figure 2, Plate II, Figures 8 and 11, and most all *A. holbrooki*, Plate V, Figure 26, all have rays which are longer than the direct distance to the peripheral rim plates. The rays of *A. austini* at their outer ends turn slightly at the peripheral rim. *A. pileus* may parallel the rim with the tips of the rays for some distance. In *A. cincinnatiensis* the rays at their distal ends leave the rim and point back toward the center. The diagnostic character of *A. holbrooki* is that the tips of the rays return from the peripheral rim perhaps one-third of the distance toward the mouth region, dividing each interambulacral region at the distal edge into two parts. I have never seen a small specimen of this form and see no reason why it may not be an exceptionally aged *A. cincinnatiensis*.

In all the species thus far mentioned the cover plates tend to be triangular or quadrangular with a spur on the proximal face of the plate between it and the next plate toward the mouth on the same side. It is difficult to identify such a spur always in the case of *A. cincinnatiensis* and I assume that it may have been merged into the flange of the groove of the outer row of cover plates and have been lost from the inner row entirely. It probably had to do with the muscular attachments of the plate.

The genus Streptaster is characterized by covering plates which are proportionately longer and more slender and which interlock in a slightly different way. One specimen from the Dyer collection shows a series of alternating small median plates as well. If the double series of plates is normal for *Streptaster* the inner row is lost to view in essentially all specimens found.

PERISTOMIAL PLATES (ORAL SIDE).

According to Zittel the characteristic number of peristomial plates is four. Foerste's diagram of *A. pileus* shows five special plates in the region of the mouth. The number of especially large peristomial plates is usually three, one large, roughly triangular with one angle toward the posterior inter-radial space and the other two angles lying along the line between the junctions of rays one, two and rays four, five, and two smaller quadrangular plates opposite the large plate. These quadrangular plates are in line with the rows of cover plates, which make the third or anterior ray.

There is a good deal of variation in these peristomial plates. Meek's figure of *A. cincinnatiensis* in the Ohio Geological Survey shows a modification of the pattern. The Dyer collection has an *A. pileus* in which the posterior plate as shown is in two parts. Figure 13, Plate III of *A. austini* shows a much more primitive condition of these plates. Another modification is shown in Figure 52 of Plate IX. Figure 54, Plate IX is the diagram of the center of a specimen of *A. rectiradiatus* from Cherry Fork, Adams County, showing the component parts of these peristomial plates as indicated by lines of fusion on plates.

The primitive condition of the peristomial region is best shown in *Streptaster*, a specimen from the Dyer collection. In most specimens of *Streptaster*, since there is a great reduction in diameter and length of the cover plates in the mouth region and since the plates over the rest of the food groove are so hypertrophied the peristomial region is rarely seen. Figure 47; Plate VIII, a diagram of the specimen mentioned, shows the small mouth plates with very little fusion into special plates. The plate marked P. shows by its grooving that it is a union of three simple plates. There is no way of distinguishing any definite anterior plates as there are three plates where one would expect the anterior peristomial plates R. and L.

The large peristomial plates described above, then, are made by fusion of a number of simple cover plates and may include the nearest inter-radials as well. This fusion often does not take place or at least does not take place completely in many cases.

PERISTOMIAL PLATES (ABORAL SIDE) AND PLATES FORMING SUBSTOMIAL CHAMBER.

The substomial chamber has been described in detail by Foerste from the Miller and Faber specimen of *A. pileus* and others. In most cases deformation of the specimen makes the aboral pattern very hard to unravel.

The material from Lawshe, which, for the purpose of this discussion, I will call *A. austini* var. Lawshe is all exposed from the aboral side and furnishes some additional information. The aboral view of the large peristomial plate P in the posterior inter-radial space has been obtained in several specimens. See Plate II, Figure 12 for plate out of its relative position. Foerste's description of it as ridged like the letter W on its surface toward the substomial cavity gives a good idea of that surface. This plate is shown rather indistinctly in Figure 44, Plate VII as two masses in the anal inter-radius. The portion of the plate toward the anal pyramid consists of a heavy ridge extending the length of the plate at right angles to the W into which the tops of the W like ridges merge. From this ridge posteriorly the plate extends toward the anal pyramid about the same distance as from the proximal part to the ridge, becoming thinner all the way until it unites with the other plate of the posterior inter-radius.

The same plate shaped somewhat differently and not differentiated at its left (aboral) end from the rest of the plates is shown in the aboral diagram of *Streptaster*, Figure 48, Plate VIII.

Foerste states that the two anterior peristomial plates are represented on the aboral side by triangular ridged plates in the Miller and Faber specimen. Figure 6, Plate I, represents a side view of an *A. pileus* which has lost its arms 1 and 5 and the posterior plate P. This same specimen is photographed from the oral side in Figure 4, Plate I. The R. and L. peristomial plates are shown edge on and as far as this specimen is concerned the plates appear thickest at the peristomial face and seem to thin out in the anterior direction.

In the best preserved of the Lawshe specimens the substomial chamber is bounded definitely by the five first flooring plates with their projecting lateral processes and the posterior peristomial plate. See Figure 44, Plate VII. In other individuals this is not so plain. In one instance it appears as if a lateral process of a first flooring plate is cut off short and is connected with the lateral process of the flooring plate of the next ray by a small plate of its own width abutting directly on it.

The condition of the peristomial ring which corresponds with the Miller and Faber *A. pileus* is shown in the aboral diagram of *Streptaster*, Figure 48, Plate VIII. Here we have the first floor plates of rays 1 and 2 united closely, a plate projecting aborally between the first flooring plates of ray 2 and ray 3, a somewhat similar plate projecting between the first flooring plates of ray 3 and ray 4 and the first flooring plates of rays 4 and 5 closely united.

If we consider the oral surface again it is clear that this condition might have been expected. The oral slit is elongate from right to left, the rays 1 and 2 closely approximated at their proximal ends, the rays 4 and 5 also closely united and both sets distinctly separated from the anterior ray. In *A. austini*, at least in the variety lawshe and in the small

Agelacrinite from the Elkhorn, Figures 25 and 25A, the five rays are rather close in their origins and the aboral extensions of any plates to stiffen the peristomial ring would be less necessary. There may be sometimes a small plate in place between rays 2 and 3 and rays 3 and 4, but it is not sufficiently elongate aborally to call attention to itself, in most cases. Nor does it seem as though in the specimens at hand the R. and L. peristomial plates were far enough apart to be represented from the aboral side as these stiffening plates. I should prefer to consider these two intervening plates when present either as descendants of cover plates between the pairs of rays and anterior ray or possibly they might be the first inter-radial plates of the inter-radial areas in which they lie.

It has been shown that the posterior peristomial plate is made by the fusion of plates, the middle one of which might be considered as the apex of the anal inter-radial space. The anterior peristomial plates likewise must be made up of a fusion of cover plates, but I have no evidence that there are inter-radial plates involved. Hall calls these plates V shaped and if they are made of cover plates from ray 3 and of cover plates from between rays 2 and 4 the V shape would be the natural shape. Most that I have seen, however, are quadrangular and so there is the possibility of the incorporation of the first inter-radial plates from the respective areas.

FLOORING PLATES.

After the first flooring plates of each ray which surround the substomial chamber with the help of the posterior peristomial plate, the ray as seen from the aboral side is continued as a series of quadrangular plates, upon which the covering plates already seen from the oral side stand. These floor-plates join each other by a slightly beveled joint, the proximal end of each plate sliding slightly over the distal end of the next plate inward toward the mouth. This joint has the greatest slant or bevel in *A. cincinnatiensis* and the least, almost a vertical joint, in *A. austini* var. lawshe.

There is another beveling of these plates on the lateral (oral) surfaces in *A. cincinnatiensis*. On these lateral slanting surfaces stand the outer row of cover plates. I do not find this articular surface on those forms which have less nearly two pairs of rows of cover plates for each ray.

In *A. austini* var lawshe there are in the adults nine flooring plates after the substomial plate in each ray. Figure 41, Plate VII, shows most of these flooring plates in one ray or another. In this species there are about three pairs of cover plates for two flooring plates.

In *Streptaster* we have the primitive condition, one pair of cover plates standing on a single floor plate. This will probably hold good in the case of *A. rectiradiatus* when the flooring plates of this species are known.

In developing forms of *A. austini* var lawshe to be considered later it is quite clear that a flooring plate of the adult is made from two primitive flooring plates a proximal and a distal, fused. The crowding of the cover plates toward alternation and hence toward doubling already considered is a character which is correlated with this fusion of primitive flooring plates.

ABORAL ENDS OF COVER PLATES.

Here again the material from Lawshe gives some precise information. The condition of cover plates in Miller and Faber's specimen of *A. pileus* as described by Foerste is not common either for the specimens of *A. pileus* at hand or for *A. austini* either from Dutch Creek, Cowan's Creek or Lawshe. In the Miller and Faber specimen cover plates are described with a long basal process extending away from the ambulacral groove and under the edge of the inter-ambulacral plates.

In the Lawshe specimens the aboral end of cover plates is shown in many cases where the floor plate of the ray has slipped. The plate ends rather squarely with two enlargements one the point of articulation with the flooring plate and one more oral in position, which must have been for muscular attachment. It is this enlargement or a point just above it which must be prolonged as the basal extensions of the lateral covering plates in *A. pileus* Miller and Faber and in *A. cincinnatiensis.* A few of the plates on *A. rectiradiatus* show an extension somewhat similar to these. Might it not be that in aged specimens there was a deposit in the tissues attached to these plates so as to produce these basal extensions?

Between the enlargements on the bases of two adjoining cover plates in *A. austini* var lawshe is left a small circular opening which would connect between the radial food groove and the visceral cavity, Figure 43 A, Plate VII. These openings are shown distinctly in many of the specimens and are not accidental. They would serve as passages for podia or other tubes of an ambulacral system.

The bases of the covering plates in a specimen of *A. pileus* is shown in Figure 7, Plate I. This indicates also the very small size of the food groove (in front of the black arrow) which ran beneath the cover plates and above the row of flooring plates.

Rate of Growth.

If size can ever be considered a specific character the forms under consideration range from *A. holbrooki*, over 30 mm. in diameter, *A. cincinnatiensis*, 27 mm., *A. pileus*, 20 mm., *A. rectiradiatus*, 17 mm., *A. austini* var. lawshe, 17 mm. to *A. austini* from Dutch Creek, 10 mm. The numbers of pairs of cover plates in the ambulacral ray corresponds roughly with the diameter of the specimen.

Where the plates at the beginning of the ray were indistinct the number is preceded by an x, where indistinct at the distal end the number is followed by y. Only the outer row of cover plates was counted in any case.

TABLE.

Diameter in mm.	1	2	3	4	5	Species	Source, if not Collected
30	..	..	x38y	..	..	holbrooki	Dyche
21	x21	x23	27	24	x22	cincinnatiensis	Dyer
15	..	16y	24	23	..	pileus	Dyer
15	18y	18y	24	20	17y	pileus	Dyche
14	11y	12y	21	x19	x20y		
13	23	20	20	19y	21	cincinnatiensis	Dyer
12	20y	..	20	16	x16y	cincinnatiensis	Dyer
12	x20	x21y	12y	17y	16y		
10.5	15	13y	15	x12y	13y		
10	20	21	20y	10y	14y	cincinnatiensis	Dyer
10	x10	17	x16	..	..		
10	18	..	15	..	..		
7.5	15	13y	15	..	13		
6	13y	..	12y	..	x15		
6	16y	15y	13y	..	..		
6	7	6	4y	x4y	5y	cincinnatiensis	almost straight rayed

These arms which were notably deficient or indistinct were omitted entirely from the count; those unnamed being *austini* or related forms.

One is often under the impression that a fossil, being ancient, must have lived a long time. This, of course, is not at all necessary. Among the numerous specimens with their aboral faces up collected at Lawshe, Figure 10, Plate IV, shows some 30 which had been seated upon a valve of Ischyrodonta ovalis(?). The largest of these is not 3 mm. in diameter and the smallest less than half that. On the same rock, Plate IV, Figure 14, is another group of five individuals which cover a similar shell nearly as fully. These range from 10 to 12 mm. in diameter. On another rock fragment I have one *Agelacrinite* approaching the larger size and several small ones about it, none over 3 mm.

There is no doubt in my mind that the specimens of 3 mm. or less attained that diameter during their first season's growth and that the ones which survived for a second season reached the larger dimension. A specimen which measures 17 mm. from this same locality may have grown for three seasons.

Dr. A. D. Mead, in the American Naturalist for January, 1900, showed that in the case of the starfish the rate of growth depends definitely on the food supply. He there gives a diagram of two starfishes of the same age (two months) the one about the size of a pinhead and the other 2.5 inches in diameter. The size also determined the sexual advancement of these starfishes and those of a certain size were mature, no matter what the length of time needed to reach that size. "We are warranted in inferring therefore that well nourished starfish arrive at sexual maturity and breed before they are a year old."

If we suppose these *Agelacrinites* were able to reproduce the second season we have evidence of a colony located at the top of the Richmond sea-deposit near Lawshe which must have had favorable conditions for at least two seasons of growth and probably three, since there are three well defined sizes represented on the clam valves. Of these the smallest specimens (up to 3 mm.) are by far the most abundant, hundreds of them being found on a single piece of rock. The size 10 to 12 mm., is rather common and the very largest, 17 mm., are represented by few individuals.

The smallest specimen identified was two-thirds of a millimeter in diameter and showed the aboral face. The smallest specimen oral side up is 1.5 mm. in diameter.

Concerning Possible Locomotion.

These animals are usually considered sessile and of course there is no direct evidence as to their locomotion. It is, however, possible that they may have been able to move and this is suggested by Clark, 1901.

The specimens of *A. austini* from Cowan's Creek are usually found unattached and aboral side up. This may be merely evidence of the loosening from the shell on which the animal had lived after its death.

The material from Lawshe shows clam valves with numerous young specimens, Fig. 20, and valves with fewer larger specimens, Fig. 24. It is possible that as valves were overcrowded some died and dropped off and the survivors occupied their space; but it is also possible that they simply moved away as they outgrew the place of attachment.

Dr. G. H. Parker has shown for gastropods that animals which show no pedal waves still may have the same type of muscular movement in a different form which will result in locomotion.

Furthermore, he finds the same type of locomotion illustrated in the *Actinians* among the *Coelenterates*, resulting in the case of *Condylactis* in an advance of more than a centimeter in three minutes.

Psolus fabricii, the recent holothurian, already referred to with reference to the peripheral rim, has a muscular "sole" which may be of much the same type as the aboral attachment of *Agelacrinites*. In spite of the distant relationship between these two forms, why may not the close parallelism between the skeletons of the two, be accompanied by the same ability to creep in the *Agelacrinites* as the *Holothurian* has?

Respiration.

It is obvious that an animal whose body is protected by so complicated a series of plates would not be able to breathe easily directly through the outer wall. The clue for the respiration is found in the related group of the crinoids. In Antedon (Parker and Haswell, Vol. 1), the rectum projects as the tubular papilla and the rectal tube is in the living animal seen to undergo frequent movements of contraction and dilation by means of which water is drawn into and expelled from the rectum. There is thus intestinal respiration.

In *Agelacrinites* the anal pyramid, which seems to be composed of either a single ring of triangular plates or this ring under-laid by a supplementary series of plates (a total of from 6 to 20 plates then, depending on the species) must have been part of a similar respiratory device. Whatever oxygenation might have taken place along the food groove, there certainly could have been a large gaseous interchange from the rectal water content through its walls to the coelomic fluid and thus to all structures in the body. Figure 2, Plate I, Figures 15, 18 and 19 of Plate III, Figure 29, Plate V, Figures 22 and 23 of Plate IV, Figure 33 of Plate V, show the plates of this pyramid. Figure 41 of Plate VII, and Figure 52 of Plate IX, are diagrams of the pyramid as seen from the aboral side.

The starfish is said to have plates in the walls of the stone canal and it is possible that these plates may be related in a similar way to the mechanism for keeping the ambulacral system of the starfish full of water.

Water System.

Not much information on this subject is furnished by the specimens at hand. In one specimen from the Dyer collection, Figure 2, Plate I, there are two plates in the ink circle in the posterior inter-radial space by the proximal end of arm 5 which appear as a duct had passed between them.

A specimen marked *A. pileus* in the Geological Museum of the Ohio State University shows a plate in this same region which has a distinct pit or pore in it.

Another specimen of *A. pileus* seen has this same plate, but instead of a pore there is a notch on the edge of the plate next the inter-radial space.

According to Bather this is the location of the hydropore, or one of the hydropores, which correspond to the madreporic body in the starfish. He suggests that there may be as many as five hydropores present, but I have been able to find traces of this one only.

Two specimens showing the aboral side from the Elkhorn demonstrate corresponding pits next to ray 5 on the left side of the substomial chamber in the inter-radial area which contains the anal pyramid. The pit gives little evidence as to the direction the water tube took. From the presence of the circular openings between the cover plates on each side of a ray one would assume a ring canal just outside the bases of the substomial chamber plates and a double radial water tube, one on each side of the ray. Figure 25 and 25A, Plate IV.

Stages in Development (aboral side).

The specimens from Lawshe were from 17 mm. down to two-thirds of a mm. in diameter, as stated above. Only a very few of them showed the oral side.

In the section on the rate of growth attention was called to the great numbers of specimens which were found on single clam valves. The usual size of these abundant specimens is 2 mm. in diameter and less. From these specimens showing the aboral face a series has been selected to show the increase in flooring plates.

The first one, Figure 38, Plate VII, 1.3 mm. in diameter shows the ring of first flooring plates which make the boundary of the substomial chamber. In this specimen the anal pyramid was not to be distinguished and the arms are not numbered. Figures 39, 40 and 42, showing 2, 3, and 4 flooring plates respectively, are drawn to the same magnification as Figure 29 and the arms are marked with the numerals they would have if the specimens were oral side up. The anal inter-space is marked with the letter A.

Only the first and fourth of these diagrams attempt to show all the plates of the aboral side. The specimens are so delicate and the plates so easily disarranged in death and fossilization that it is exceptional in these small-sized specimens to find a pattern that can be worked out completely.

Specimens 1.3 mm. in diameter from the oral side—Plate VI, Figure 35, shows a group of small animals from the oral side. Several of these are indicated by circles for easier recognition. Figure 55, Plate IX, is a diagram of the plates of a number of specimens. Figure 37, Plate VI is one of the three outlined in Figure 35, but photographed with a higher magnification. The broad white arrow is pointing toward the anal pyramid, which may consist of four or six plates. The rest of the disc inside the rim is not clear, but is made up of comparatively few plates. Without doubt this animal has but one row of floor plates and if seen from the aboral side would be like Figure 38, Plate VII. There are just two rows of plates in the peripheral rim. I cannot differentiate radial and inter-radial plates in these small specimens. Since, as I have shown above, there is a possibility of a fusion of cover plates to form the peristomial plates of the adult, there may not yet be represented more than enough plates to make these and the differentiation into radial and inter-radial plates may first occur at a larger size.

By the time an individual developed its second (adult) floor plate in each arm, the one outside of the five bounding the substomial chamber, it should have two or three pairs of small cover plates to indicate each arm on the oral side and the inter-radial plates should be distinguishable. Such an animal should be 2.5 mm. in diameter and none of this size were found with the oral side exposed.

Alimentary Canal.

These very young specimens from the aboral side show plainly what I take to be the path of the alimentary canal. The skeletal plates are delicate, the animal a rapidly growing one and it would be more likely that an animal killed with the intestine dilated with food would have the position of the skeleton modified by this intestine than that of a similar full intestine would change the shape of the skeleton of an adult.

Attention was called to this matter by finding numerous cases of a seeming break in the skeletons of these small creatures as seen from the aboral side. There is a depression extending around the substomial chamber and just within the peripheral ring. This depression begins at the posterior part of the substomial chamber and is continuous with its cavity just at the point where the aboral part of plate P will be in the adult. It extends around just outside the first (and only) floor plates from the anal inter-radial space back to this same interspace again. The alimentary canal would occupy just such a position if it passed posteriorly out of the substomial chamber and made a complete circle around in the body cavity between the peripheral rim and the ring of the first floor plates, to connect with the anal pyramid in the posterior inter-space. Plate VI, Figures 32 and 34 are photographs of two specimens showing what I have just attempted to describe. There is no way of deciding in these specimens whether the alimentary canal, after leaving the substomial chamber posteriorly, twisted to the right or to the left. Both photographs show the depression, constricted at each floor plate and expanded between floor plates around the whole central ring. If one were to make a guess, the intestine may have turned in a counter-clockwise direction (oral orientation) to the left in each photograph and with four inter-ambulacral enlargements may have reached the anal pyramid at a point very close to where the intestine left the posterior inter-radial space.

Summary and Conclusions.

1. Agelacrinites was probably somewhat motile, at least able to adapt its skeleton to its surroundings.

2. The peripheral rim may have been extensible.

a. Evidence from the downward dropping of the inner rim plates.

b. The great redundancy of the large plates in some of the species for simple support.

c. Processes, probably for muscle attachment, on the aboral side of the most of the rim plates.

3. The animals in the Lawshe colony were probably sexually mature the second season (by analogy from the star fish).

4. They breathed by muscular protraction, extension and retraction of the anal pyramid, getting oxygen by rectal respiration.

5. The cover plates are variable in their arrangement, the primitive condition being a single row on either side of the brachial groove and the most complex a double row, an outer large row and alternating with these an inner, small row on either side of the arm. Transitions between these two conditions are shown.

6. There is a hydropore in the posterior inter radius near the posterior peristomial plate and near arm 5.

7. There are passages between the bases of the cover plates at their aboral ends which probably have to do with a water-vascular system.

8. The peristomial plates are derived from the primitive cover plates, and in the case of the posterior peristomial plate at least also from the primitive inter-ambulacral plates by a greater or less amount of fusion. Streptaster furnishes the most primitive condition of peristome.

9. The substomial chamber is made by five specialized flooring plates and the posterior peristomial plate mentioned above. Some species may have two additional plates, one on either side of the anterior first flooring plate.

10. Cover plates one pair to a floor plate to nearly two pairs (outer) to a floor plate. In the latter case the flooring plate is two primitive floor plates fused.

11. Stages with one, two and three floor plates are shown.

12. The probable path of the alimentary canal in the small animal is shown.

I wish to thank Mr. W. McCord, of Cincinnati, for the privilege of studying his specimens of *Agelacrinites.* Also Dr. H. L. Clark, of the Museum of Comparative Zoology, Cambridge, Mass., for specimens of the recent *Holothurian Psolus fabricii* from Grand Manan. Also Dr. W. H. Shideler, for the use of his material.

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DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. Specimens of *Agelacrinites* attached to *Dystactospongia Madisoniensis*. Coll. W. H. Shideler, Fallen Timbers Creek, Indiana. X. I.

Fig. 2. *Agelacrinites cincinnatiensis* showing the effect on the peripheral rim of crowding against a *Lichenocrinus*. Dyer coll. × 3.
Also shows the hydropore (?) between two plates near arm 5.

Fig. 3. *Agelacrinites pileus* to show the outer smaller plates of the peripheral rim. × 4.

Fig. 4. *Agelacrinites pileus* with peristomial Plates L and R in position and P dropped out. Seen from above. × 4.

Fig. 5. An *Agelacrinite* having long cover plates like those of *Streptaster*. Possibly is *Streptaster*.

Fig. 6. Edge view of the same *A. pileus* photographed in Fig 4., showing the thickness of the median edges of the special peristomial Plates L. & R. × 4.

Fig. 7. Aboral side of an *Agelacrinites pileus* with flooring plates dropped out and with the arrow indicating the narrow food groove on the aboral side of the cover plates of one arm. × 4.

PLATE II.

Fig. 8. *Agelacrinites cincinnatiensis* showing the cover plates of the outer and inner series for almost the whole extent of their length on a part of food groove 1 as cleaned. Dyer coll. × 2.5.

Fig. 9. *Agelacrinites cincinnatiensis* showing food grooves 2 and 3 with the peristomial region. McCord Coll. × 2.5.

Fig. 10. *Agelacrinites pileus* showing the single cover plates of the food grooves and the inter radial plates. Dyer Coll. × 3.

Fig. 11. Fragment of *A. cincinnatiensis* showing especially the numerous rows of large plates in the inner part of the peripheral rim, and the cover plates of one side of the distal end of a food groove. W. H. Shideler Coll. × 3.

Fig. 12. Aboral views of two specimens of *Agelacrinites austini var lawshe*. Upper specimen shows the detailed aboral view of the posterior peristomial plate.
Lower showing in part peristomial chamber and the oral view of a flooring plate of a food groove. × 3.

PLATE III.

Fig. 13. Camera diagram oral view of all plates (disc, peripheral ring, margin) of a specimen of *Agelacrinites austini* (Foerste) from Dutch Creek. W. H. Shideler Coll. Anal pyramid plates put in from another specimen. × 5.

Fig. 14. Photograph of specimen diagrammed in Fig. 13. × 4.

Fig. 15. *Agelacrinites* to show anal pyramid. Dyer Coll. × 4.

Fig. 16. Camera diagram of aboral view of all plates of a specimen of *Agelacrinites austini* from Cowan's Creek. × 5.

Fig. 17. Photograph of specimen diagrammed in Fig. 13. × 4.

Fig. 18. *Agelacrinites pileus* showing anal pyramid with plates separated, leaving a rectal space. McCord Coll. × 4.

Fig. 19. Possibly *Streptaster reversata* Foerste. Shows peristomial plates and anal pyramid closed. McCord Coll. × 4.

PLATE IV.

Fig. 20. Group of young ***agelacrinites austini*** var. lawshe, from Lawshe, Adams County. Seen from the aboral side. On valve of *Ischyrodonta ovalis* (?). × 4.

Fig. 21. *Agelacrinites austini,* var. lawshe, to show the vertical ridges on the aboral side of many plates, especially those of the peripheral ring. × 3.

Fig. 22. *Agelacrinites austini,* var. lawshe. To show the floor plates of most of the food-grooves and the substomial chamber. Aboral side. × 3.

Fig. 23. *Agelacrinites austini,* var. lawshe. Aboral view of one of the largest specimens found. Shows one of the modified first flooring plates bounding the substomial chamber with its lateral projections.

Fig. 24. Group of older *Agelacrinites austini,* var. lawshe on Ischyrodonta. × two-thirds. As compared to Fig. 20 five specimens occupy a shell similar to the shell with over 30 specimens in Fig. 20.

Fig. 25. *Agelacrinites* from Eaton (Elkhorn) showing substomial chamber, anal pyramid and hydropore (indicated by arrow). × 4.

Fig. 25A. *Agelacrinites* from Elkhorn Creek showing substomial chamber, hydropore and a food-groove, No. 4, which has lost its flooring plates. The path of the groove is indicated by crosses. × 4.

PLATE V.

Fig. 26. *Agelacrinites holbrooki* from the Dyche collection showing the character of the re-entrant rays. × 2.

Fig. 27. *Agelacrinites warrenensis.* Photograph of the type specimen from the Dyche collection published now for the first time. According to Foerste a young *A. cincinnatiensis.* × 4.

Fig. 28. Fragments of a specimen of *Agelacrinites rectiradiatus* Shideler showing a few cover plates. The reticulate condition of two rim plates. From Grace's Run, Adams County. Coll. W. H. Shideler. × 3.5.

Fig. 29. *Agelacrinites rectiradiatus,* perfect small specimen from Cherry Creek, Adams County. Coll. W. H. Shideler. × 4.

Fig. 29A. *Agelacrinites cincinnatiensis,* perfect young specimen with nearly straight rays.

Fig. 30. *Agelacrinites rectiradiatus,* larger specimen showing the characters of the species. Elk Run, Adams County. × 3.

Fig. 31. *Streptaster vorticellatus* from oral and aboral sides. Dyer collection. The substomial chamber is shown near the bottom of the specimen seen from the aboral side, which is the lower of the two. The specimen showing the oral side is unusually perfect showing interradial plates, marginal plates and the peripheral ring plates at the upper side. × 2.5.

PLATE VI.

Fig. 32. *Agelacrinites austini* var. lawshe, aboral view of very small specimen. Showing the five first flooring plates, the substomial cavity formed by them and the circular depression or groove outside of the first flooring plates. × 40.

Fig. 34. Another specimen showing the same points as Fig. 32. × 30.

Fig. 33. A specimen, aboral view with three flooring plates under each food groove. The outlines of the flooring plates have been dotted in on the photograph. × 8.

Fig. 35. A group of small specimens from the oral side. Some of the best preserved ones outlined in ink. These probably have no permanent cover plates except what will go into the peristomial plates and only one flooring plate in each food groove. × 4.

Fig. 36. A specimen, aboral view like Fig. 33 but with four flooring plates under each food groove. × 6.

Fig. 37. One of the specimens from the oral side seen in Fig. 35 magnified 40 times. The anal pyramid of about six plates is shown and a few disc plates. There are no specific cover plates for the grooves. Food grooves four and five seem to be separating at the right. There is one row of peripheral ring plates, one row of marginal plates.

PLATE VII.

(All figures are camera drawings and are × 8.)

Fig. 38. *Agelacrinites austini* var. lawshe, minute form aboral view. All the plates distinguishable on the aboral side are outlined. The substomial chamber and peristomial ring of modified floor plates are distinct. No other flooring plates are separable.

Fig. 39. *Agelacrinites austini* var. lawshe, aboral view showing substomial chamber, peristomial flooring plates and one additional flooring plate of food grooves 1, 2 and 5. The location of the anal pyramid is indistinctly indicated.

Fig. 40. *Agelacrintes austini*, var. lawshe, aboral view. This shows food grooves with two flooring plates in addition to the peristomial ring of modified plates. The plate next the modified flooring plate on both food grooves 1 and 2 shows it double origin by a groove dividing it into proximal and distal halves.

Fig. 41. *Agelacrinites austini*, var. lawshe, aboral view medium sized specimen, all plates drawn which were distinguishable. The peristomial ring is shown open toward the anal pyramid, and with a triangular plate which is the downward projection of oral plate P, and under several of the flooring plates in food groove 1, the location is indicated of the round pores which lead to the oral side of the plate and therefore to the food groove.

Fig. 42. *Agelacrinites austini*, var. lawshe, aboral view. Specimen shows all plates distinguishable. There are three flooring plates shown in the food grooves 1 and 5, while the others are less complete.

Fig. 43. View of the flooring plates and slipped over bases of the covering plates of one food groove of a specimen of *A. austini* var. lawshe, showing the grooves between the covering plates leading out of visceral space.

Fig. 43. *A* is a similar view of a small portion of another food groove.

Fig. 44. The substomial chamber and beginning of food grooves in another specimen of *A. austini* var. lawshe. The aboral projection of plate P is distinct and also an unmarked plate at the end of groove 5 which may be the peristomial plate V displaced.

Fig. 45. Oral view of the food grooves and plates of a specimen of *A. pileus*, showing the trimeric arrangement of food grooves disguised by the separation of 1 and 2 and of 4 and 5.

Fig. 46. A section through the plates of the "rim" of *A. cincinnatiensis* to show the great number of these plates and the way they have dropped together.

PLATE VIII.

Fig. 47. Oral view of *Streptaster vorticellatus* showing the peristomial plates, cover plates and a few of the minute inter radials in inter space 4–5.

Fig. 48. Aboral view of *Streptaster*, showing the substomial chamber region and a large mass not separable into plates in the region of the 1–5 inter-radial space in which the anal pyramid is located.

Fig. 49. Two cover plates of *A. rectiradiatus*.

Fig. 50. Oral and end views of a flooring plate of *A. austini* var. lawshe.

Fig. 50A. Oral view of food grooves of *A. austini*, showing the alternation of large and small covering plates.

Fig. 51. Oral view of two floor plates of *A. cincinnatiensis*.

Fig. 51A. Oral view of food grooves of *A. cincinnatiensis*, showing the covering of all but the ends of the inner smaller row of cover plates by the outer larger plates.

Fig. 51B. End view of open food groove showing the inner covering plates dotted in position. Also end view of one large covering plate showing one small plate and the groove in which it lies.

PLATE IX.

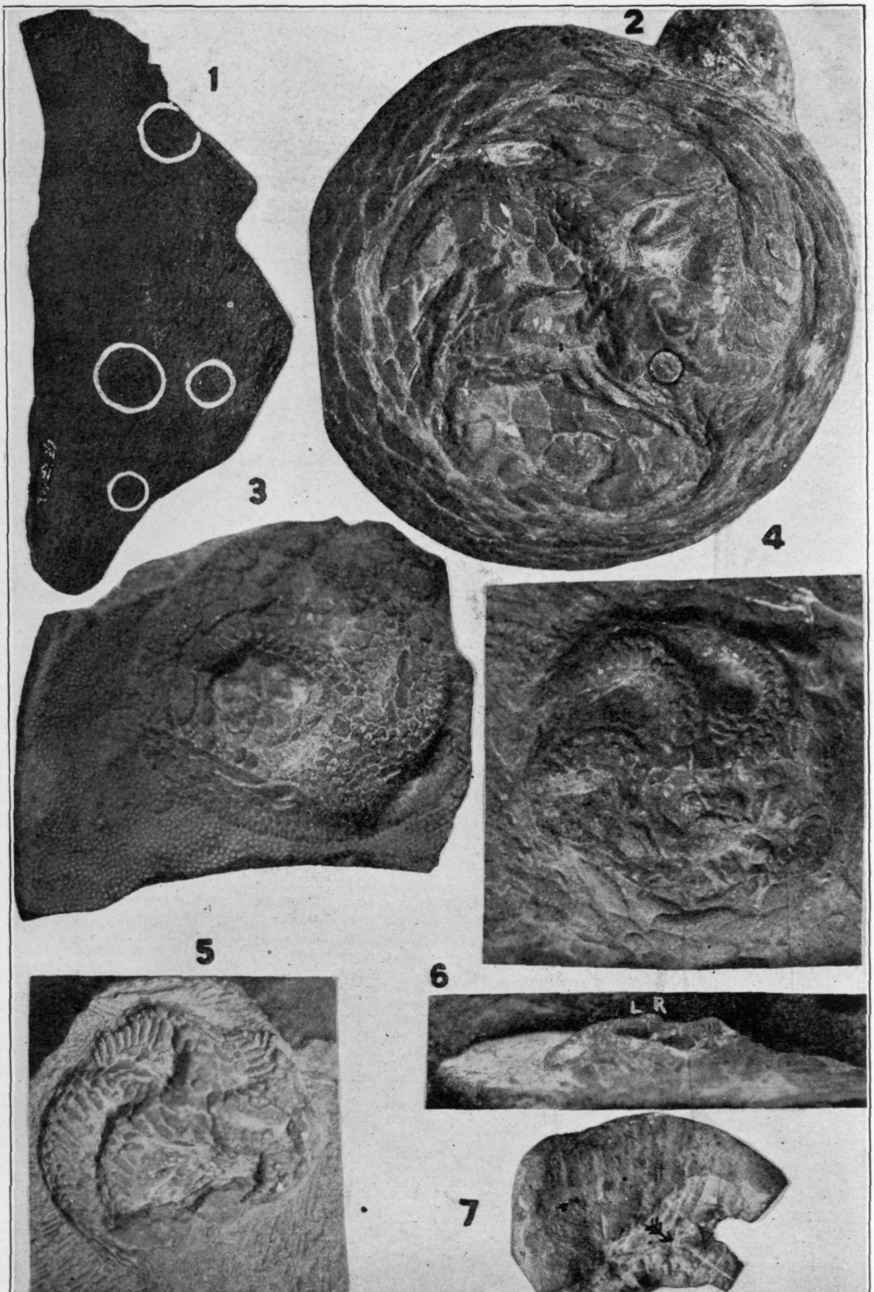
Fig. 52. Outline of oral plates and food grooves of *A. austini*, showing the union of grooves 1 and 2, and that of grooves 4 and 5 into the primitive trimeric arrangement. The large plates of the anal pyramid are 7 in number. Oral plates not united into the usual three.

Fig. 53. Oral plates and food grooves of a specimen of *A. pileus* showing elements of Plate P.

Fig. 54. Oral plates and food grooves of *A. rectiradiatus*, Shideler, diagram from small specimen. Fig, 29, Pl. V. The dotted lines indicate the probable number of plates forming the oral plates.

Fig. 55. Several diagrams of plate systems of oral side of minute specimens of *A. austini* var lawshe.

Fig. 56. Oral plates and rays 4 and 5 as shown in large specimen of *A. rectiradiatus*. Small arrow shows probable location of hydropore.



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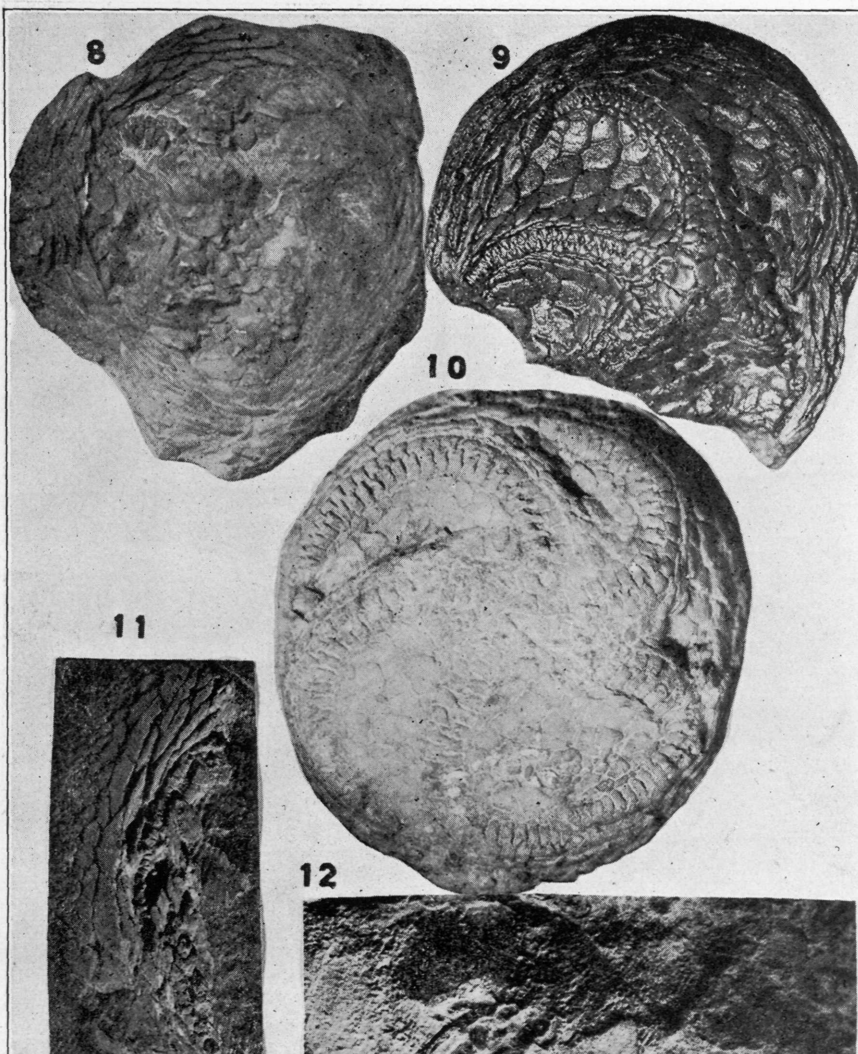

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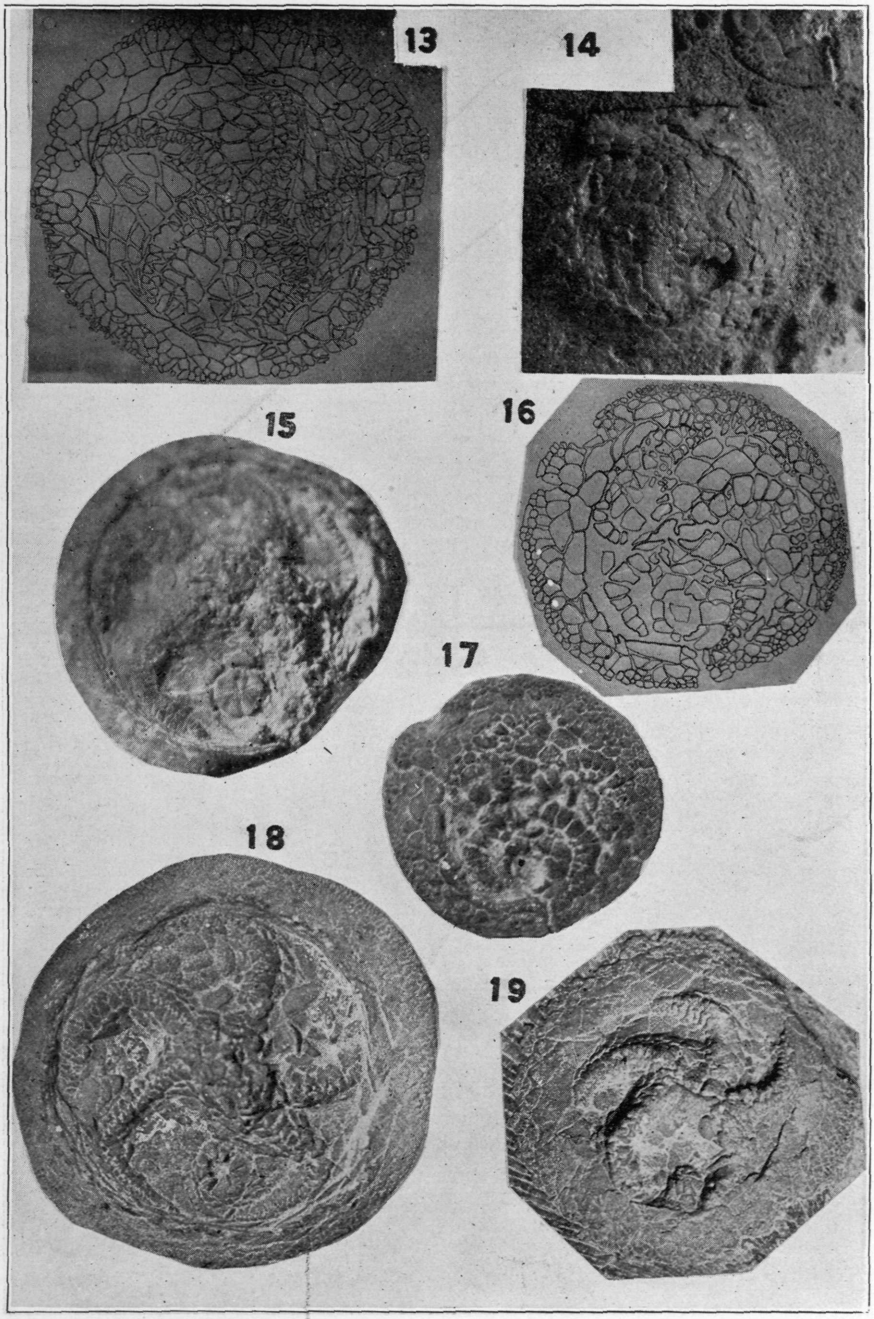

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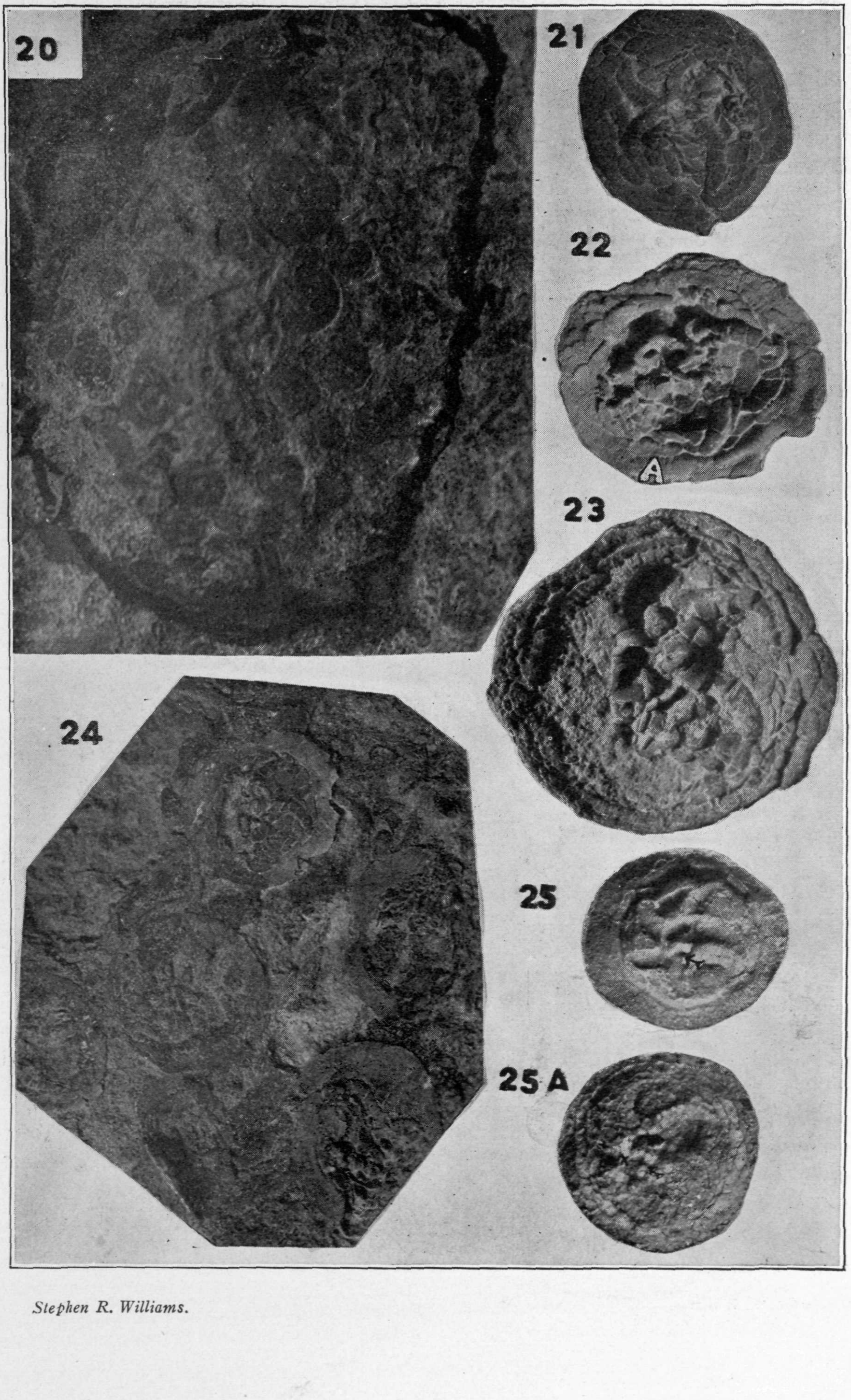

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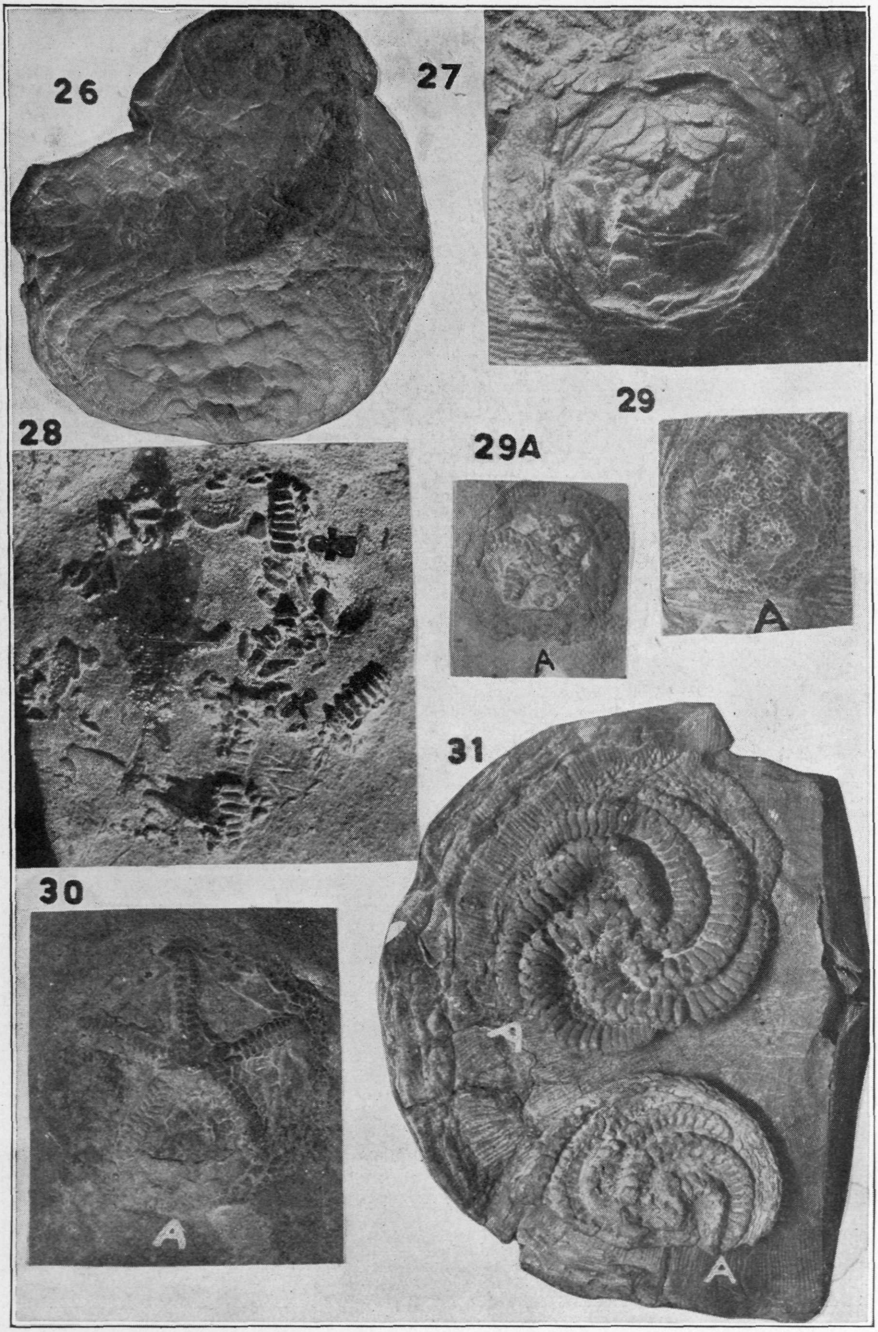

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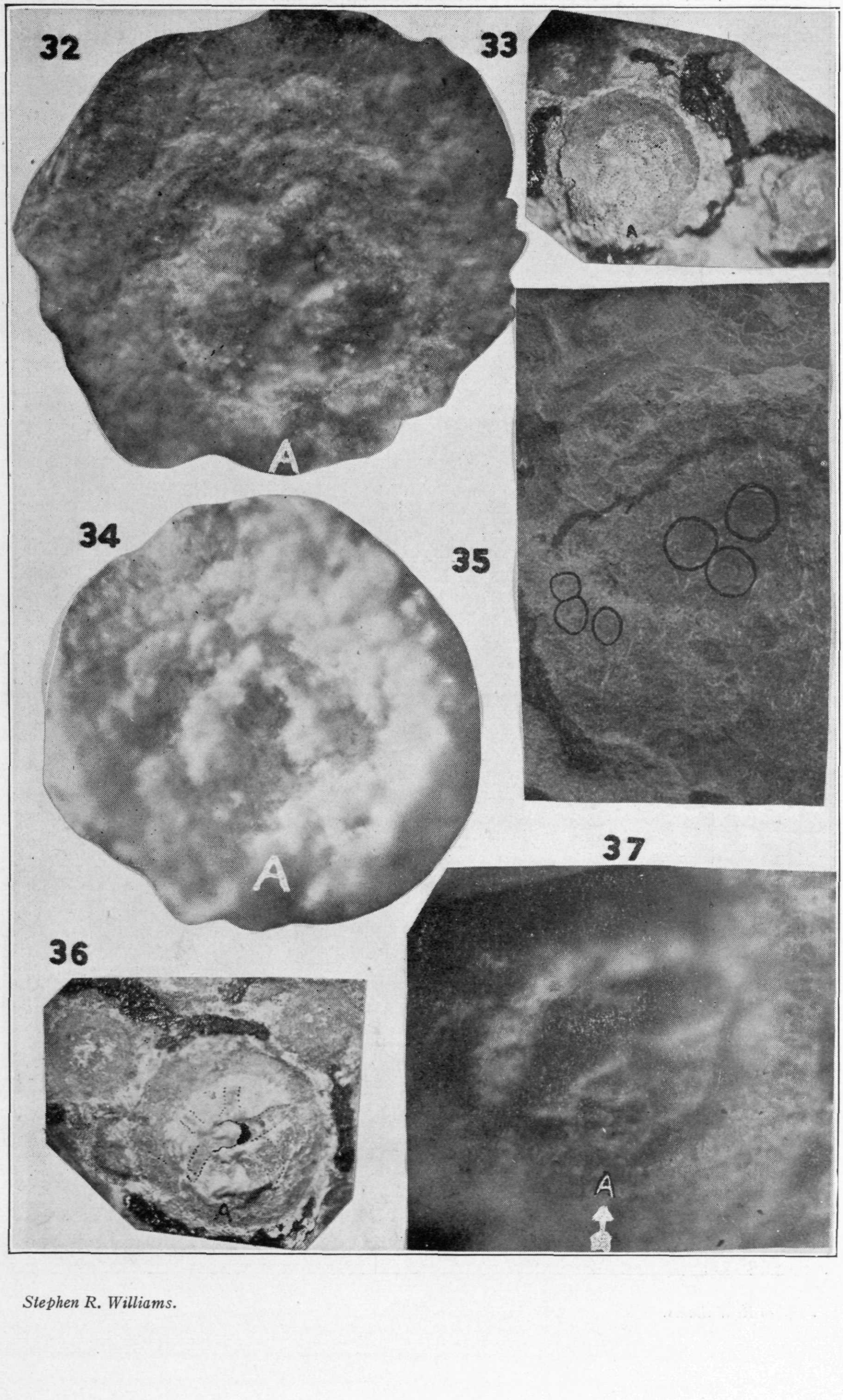

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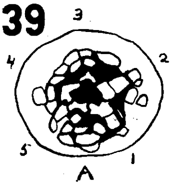

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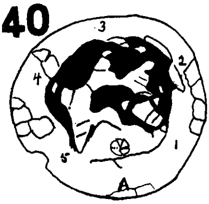

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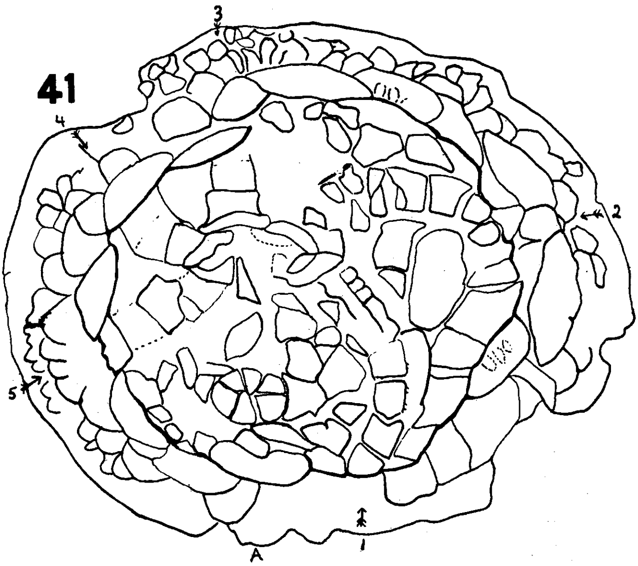

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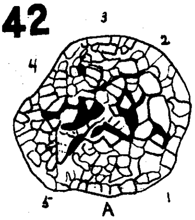

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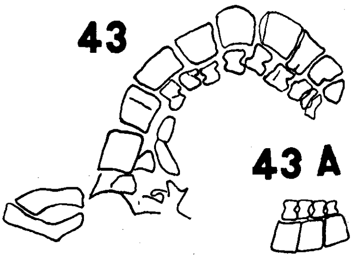

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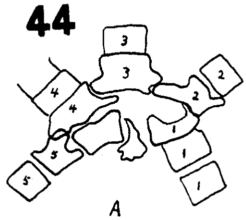

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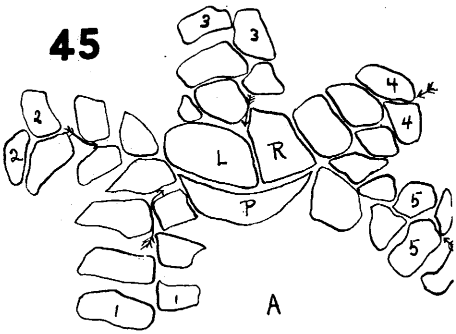

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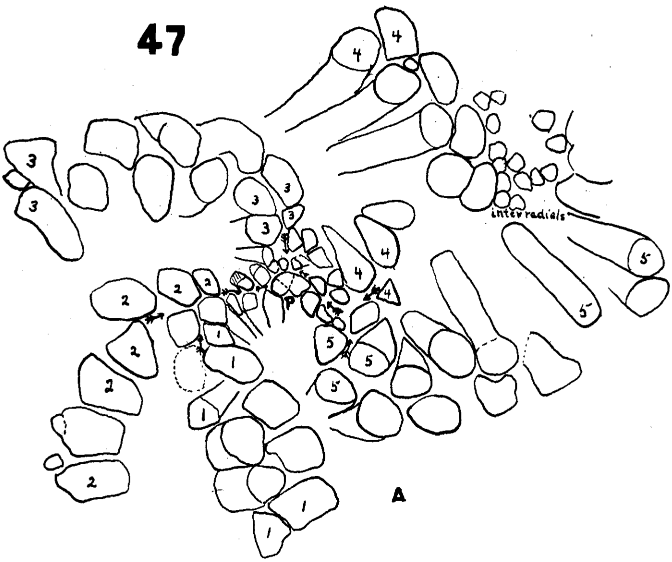

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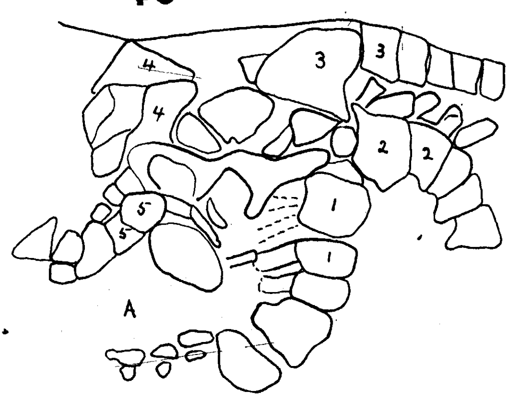

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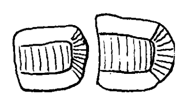

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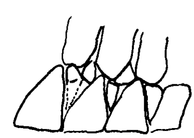

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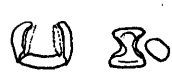

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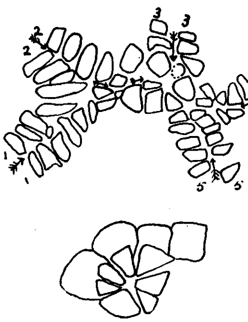

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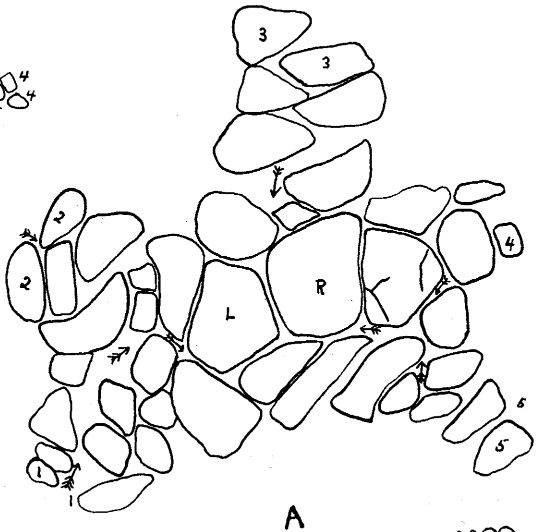

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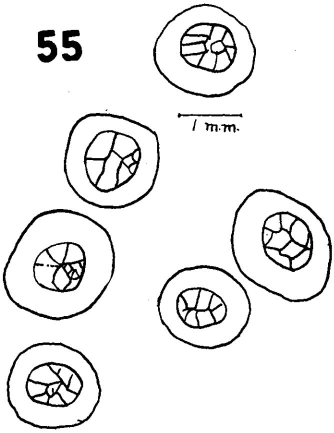

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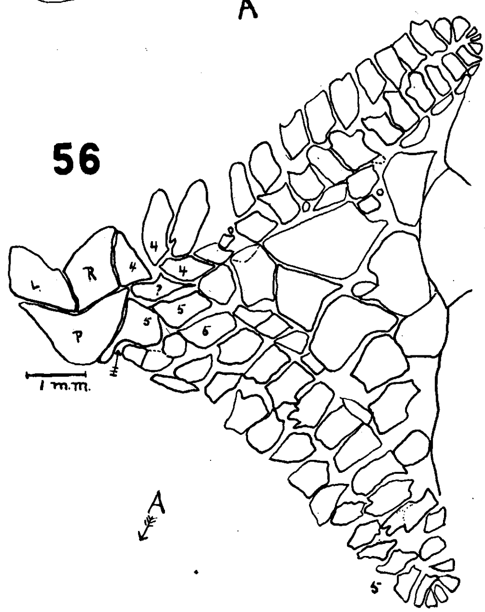

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